U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-294 982

High Volume and Gas Bubbler Sampler Preparation, Installation, and Audit Procedures

(U.S.) Environmental Protection Agency, Chicago, IL

Sep 75

EPA-905/4-75-006

PB 294982

September 1975

HIGH VOLUME AND GAS BUBBLER SAMPLER PREPARATION, INSTALLATION, AND AUDIT PROCEDURES

Region V
Regional Air Quality Assurance Network

prepared by: John Logsdon and Walter Kocal
Central Regional Laboratory
1819 W. Pershing Rd.
Chicago, IL 60609

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Table of Contents

Section	Topic
1.0	Introduction
2.0	High Volume Equipment Maintenance Schedule
3.0	High Volume Sampler Equipment Description and Service
4.0	High Volume Sampler Calibration Procedures
5.0	High Volume Sampler Field Audit Procedures and Data Reporting
6.0	Bubbler Sampler Equipment Maintenance Schedule
7.0	Bubbler Sampler Equipment Description and Service
8.0	Bubbler Sampler Audit Procedures
9.0	Station Set-up
10.0	Sampler Audit Data Evaluation Criteria
11.0	Station Evaluation and Inspection

List of Figures

Section	Figure	Title
2.2	1	High Volume Sampler Operations Flow Chart
3.2	2	High Volume Shelter Unit
3.3.1	3	High Volume Motor Assembly
3.4.1	4	Recording Transducer Unit
3.4.2.1	5	Transducer Calibration System
3.4.2.2	6	Transducer Calibration Data Sheet
3.5.2	7	Step Down Transformer - 16 volt drop
3.5.3	8	Step Down Transformer - 32 volt drop
4.2.2	9	Orifice Calibration Set-up
4.2.2.5	10	Orifice Calibration Data Sheet
4.2.2.12	11	Orifice Calibration Data Plot
4.3.1	12	Sampler in Service Position
4.3.2.6	13	Sampler Calibration Data Sheet
5.3	14	High Volume Sample Audit Data Sheet
6.3	15	Bubbler Operations Flow Chart
7.2	16	5-gas Sampling Rack
7.4	17	Membrane Filter Unit
8.2	18	Bubbler Leak Check Data Sheet
9.5	19	High Volume Sampler Support
9.5	20	High Volume and Bubbler Sampler Support
11.1	21	High Volume Sampler Inspection Sheet
11.1	22	Bubbler Sampler Inspection Sheet

2<

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-905/4-75-006	2.
3. RECIPIENT'S ACCESSION NO. PB294982	
4. TITLE AND SUBTITLE High Volume and Gas Bubbler Sampler Preparation, Installation and Audit Procedures	5. REPORT DATE September 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John Logsdon and Walter Kocal	8. PERFORMING ORGANIZATION REPORT NO
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. EPA, Region V Surveillance and Analysis Division Central Regional Laboratory 536 South Clark Street Chicago, Illinois 60605	10. PROGRAM ELEMENT NO. Manual 11. CONTRACT/GRANT NO. 5SCRL
12. SPONSORING AGENCY NAME AND ADDRESS U.S. EPA, Region V Surveillance and Analysis Division Central Regional Laboratory 536 South Clark Street Chicago, Illinois 60605	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document describes the operations required of the Environmental Protection Agency, (EPA) Personnel for set-up, calibration and maintence of Regional Air Quality Assurance Network, (RAQAN) particulate and bubbler samplers

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
	Hi-Volume Sampler	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 54
	20. SECURITY CLASS *(This page)* Unclassifield	22. PRICE PCA04/MF A01

EPA Form 2220-1 (9-73)

1.0 Introduction

1.1 This manual describes the operations required of Environmental Protection Agency (EPA) personnel for set-up, calibration, and maintenance of Regional Air Quality Assurance Network (RAQAN) particulate and bubbler samplers. Operating and analytical procedures are described in detail in other manuals.[1,2,3,4] It is not the purpose of this manual to rewrite the manufacuturers procedures, but to reemphasize and clarify certain points. Rather, portions of the manufacturers "user manuals" are referenced and applied specifically for RAQAN use.

1.2 Maintenance schedules are outlined and provide expected service, calibration, and audit intervals. Revisions of this manual will follow as experience suggests the need for change. Close adherence to the procedures in the current revision should be maintained.

2.0 High Volume Equipment Maintenance Schedule

2.1 Routine maintenance to be performed by the station operators is described in other manuals.[1,2]

2.2 High volume sampler maintenance and audits should be performed as directed by the schedule in Table I.

This schedule describes audit and maintenance outputs for each site on a relative timetable. The absolute timetable is left to the discretion of each District Office. A flow chart of the operations is shown in figure 1.

3<

High Volume Maintenance and Audit Schedule

Step	Time (months)	Operation	Output
1	0	Sampler Preparation	
2	0	Installation	
3	0	Multi-point Calibration and Single-point Audit	Calibration Curve
4	6	Two-point Audit	Audit Report, Field Inspection Sheet
5	6	Routine Preventive Maintenance	
6	6	Multi-point Calibration	Calibration Curve
7[a]	12	Two-point Audit	Audit Report
8[a]	12	Routine Preventive Maintenance	Field Inspection Sheet
9[a]	12	Special Maintenance	
10[a]	12	Multi-point Calibration	Calibration Curve
11	12	Orifice Unit Recalibration	

[a]Repeat every 6 months.

TABLE I.

4<

High Volume Sampler Operations Flow Chart

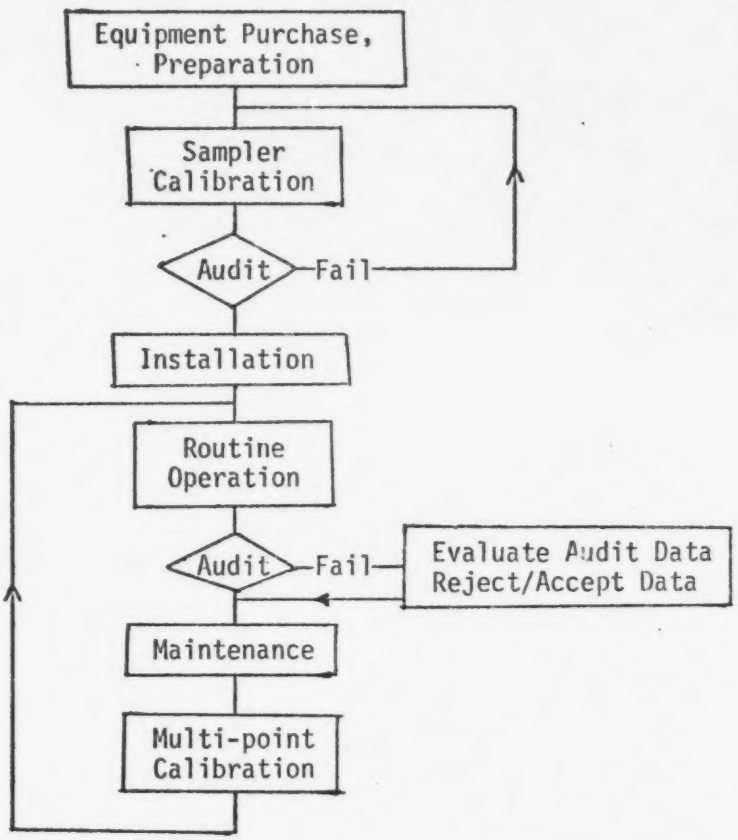


Figure 1.

5<

2.2.1 This schedule requests a number of important outputs for data evaluation and station maintenance. Samplers prepared and calibrated at the laboratory and taken to the field require an audit after installation to verify the accuracy of the earlier calibration that no damage has occured during transit. On-site calibration and audit is an alternative.

After 6 months of routine operation and pending no field operation failures during this time, a two point calibration audit should be performed. If the audit data are acceptable (criteria given in section 10.), the past 6 months monitoring data are accepted, routine and special maintenance are performed, and the sampler is recalibrated.

If the audit data are unacceptable, the air quality monitoring data will be rejected, corrective action for the sampler taken, and calibration performed.

2.2.2 Steps 7 through 10 are performed every 6 months. This schedule allows for good preventive maintenance practices and provides a continuing record of the sampler's performance.

Maintaining this schedule is essential since it provides a mechanism for identifying blocks of suspect data and qualifying blocks of acceptable data.

3.0 High Volume Sampler Equipment Description and Service

3.1 One objective of the RAQAN is to replace all existing samplers with aluminum General Metals Works* shelters equipped with 2000 H motors,

*Mention of manufacturer's name does not constitute endorsement of the equipment by the EPA or the Central Regional Laboratory.

recording transducers, voltage reduction transformers, and programmable automatic timers. Only procedures pertaining to these units will be presented. However, various combinations of these units may exist,and the specific device procedures will still apply. The procedures are formatted to illustrate installation of a new sampler. However, most procedures are applicable to old units as well.

3.2 High Volume Shelter

3.2.1 Figure 2 shows a high volume shelter unit. Assembly consists of only attaching the roof to the main unit via the hinges and removing all packing material. Check for and report any damage to new units to the CRL.

3.2.2 Check all latches for easy operation. It may be necessary to bend the latches or hinges to get a firm fit.

3.2.3 Inspect the structure for loose screws or components and make repairs as necessary. Also inspect the shelter for sharp and hazardous edges. If necessary, file the edges to avoid injury to personnel.

3.2.4 Using a 1" x 1" or 1" x 2" firring strip, cut a length of the wood strip to fit from the front of the shelter to the top of the inside of the open roof. Figure 2. This will avoid undesired closing of the roof during service of filter insertion.

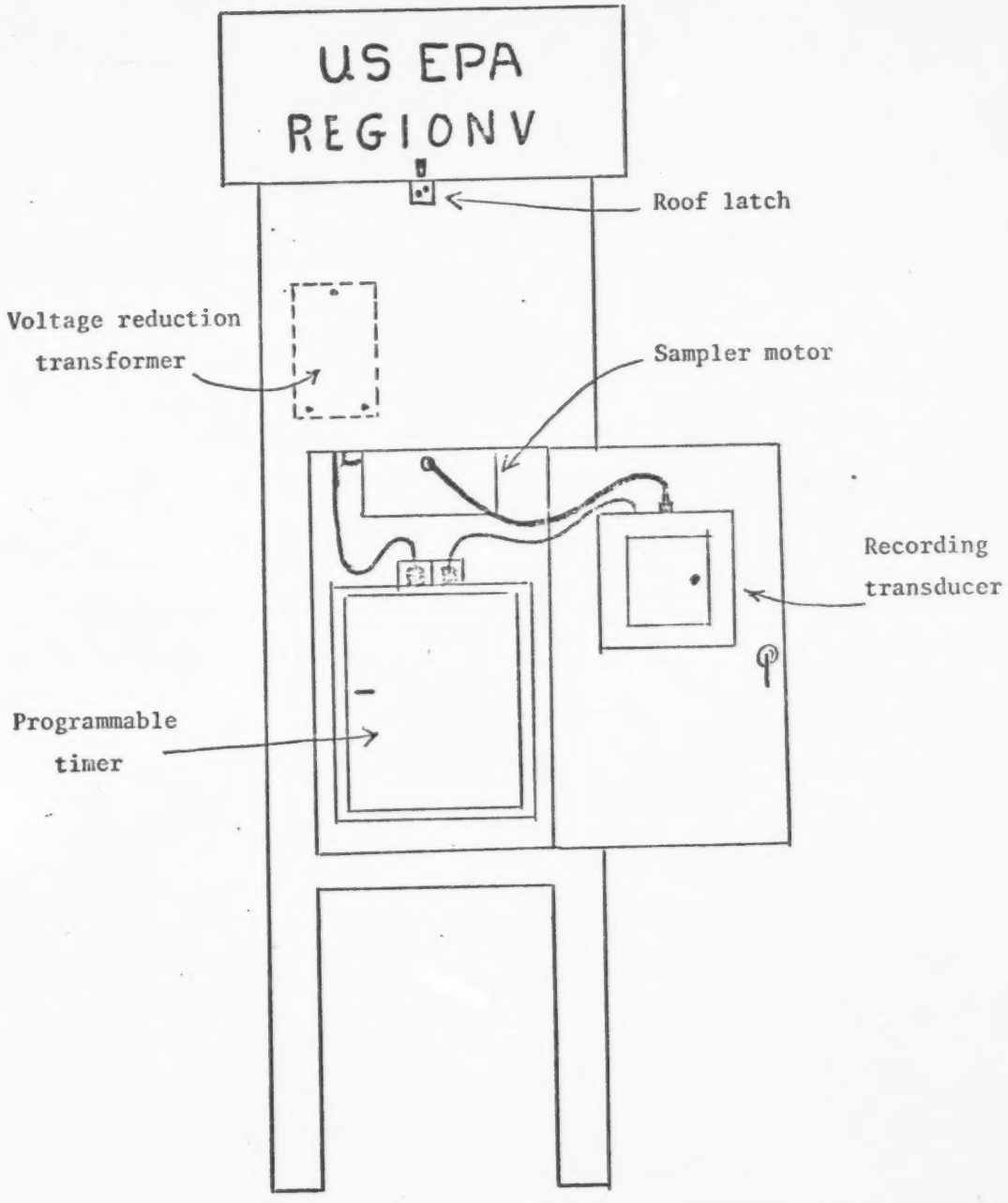
3.2.5 Using a stencil, paint the words:

U.S. EPA
REGION V

on the outside of the roof and on the side panel of each shelter. The motor number from the metal plate attached to the side of the motor should be recorded inside the shelter roof. This number

Figure 2.

High Volume Shelter Unit



must be changed to reflect any changes in the motor used, i.e., replacing a burned out unit.

3.3 High Volume Sampler Motor Assembly

3.3.1 Figure 3 shows a motor assembly and a parts schematic diagram. This diagram also shows a filter adapter.

3.3.2 Remove the motor assembly from the shelter by unplugging the electrical cable, disconnecting the pressure hose from the side of the motor and carefully lifting the motor through the top of the shelter.

3.3.3 Inspect the filter adapter for damage. Be sure that the faceplate is not bent and fits squarely on the adapter. Also, check the rubber gasket for a tight seal to the faceplate and no dried or cracked sections.

Every 18 to 24 months it may be necessary to replace this gasket. The life of each gasket is a function of the sampler location and must be checked at least every 18 months. Replace any gasket that does not seal properly or is damaged. This will be noticed by the station operator or the CRL since the filters will show rough borders for the particulate matter.

3.3.3.1 Remove the faceplate and using a razorblade or putty knife, remove the old gasket. Scrape the faceplate clean.

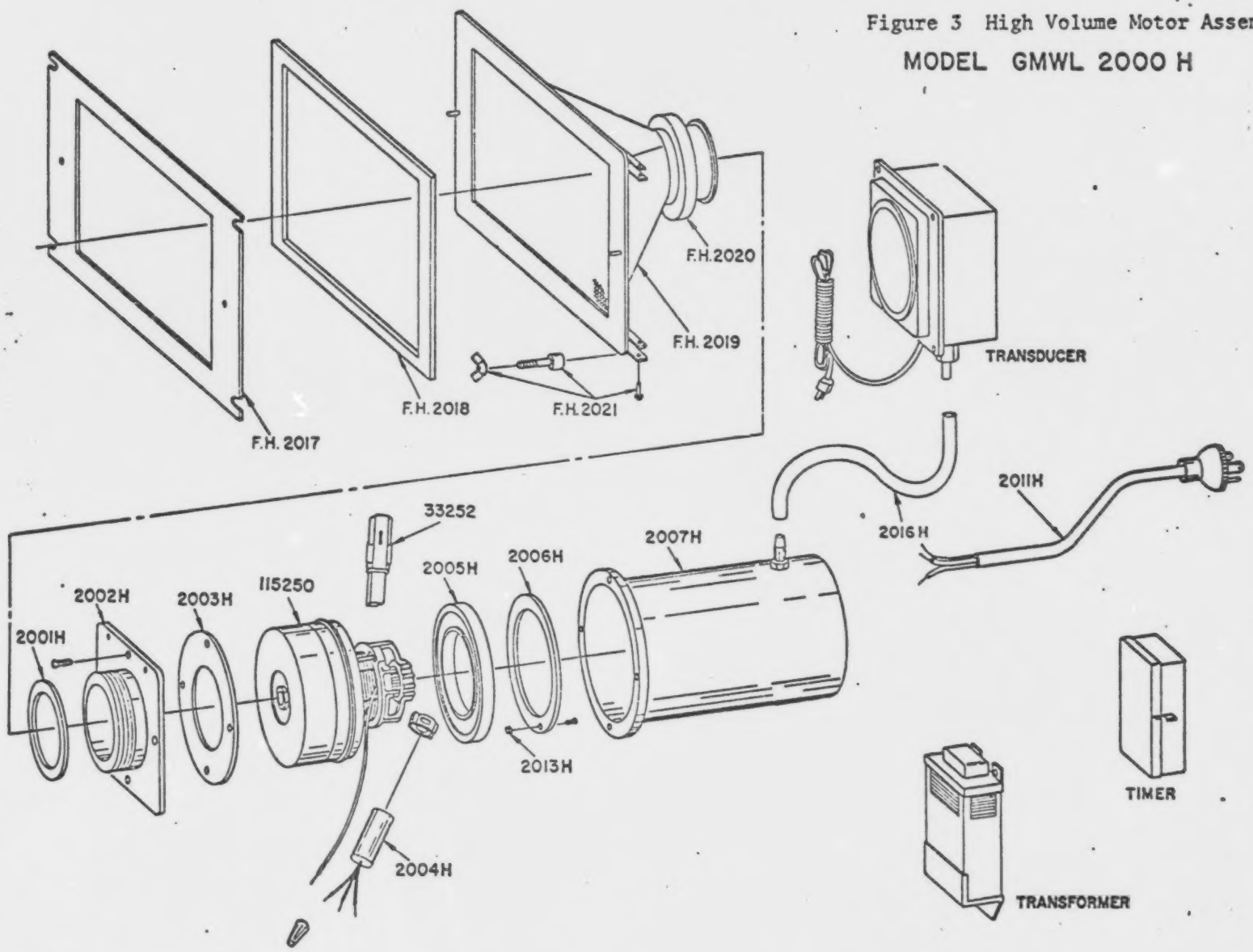
Using rubber cement, attach the new gasket, place the faceplate on the adapter, tighten the wingnut clamps carefully, and wipe any excess cement off the unit. This cement sets up quickly.

Inspect the unit to verify proper installation.

3.3.4 Inspect the retaining ring fit to be sure it is not cross threaded. Using a strapwrench (if available), tighten the ring until the

Figure 3 High Volume Motor Assembly

MODEL GMWL 2000 H



units are sealed together. Do not overtighten the unit.

3.3.4.1 It may be necessary to change the gasket under the retaining ring if the gasket is cracked and dried. Simply loosen the ring, replace the gasket, and retighten the retaining ring.

3.3.5 Motor Brush Replacement

3.3.5.1 Every 6 months the motor brushes should be replaced to avoid commutator damage and motor burnout. New motors require burn in as described in section 3.3.5.8. Refer to the GMW 2000 H manual for details.[5]

3.3.5.2 Remove the filter adapter.

3.3.5.3 Remove the 4 screws on the adapter mounting plate. Remove gasket #1, motor, gasket #2, and the ring.
Carefully push or pull the three wire cord until a sufficient working length is through the housing.

3.3.5.4 Remove the brushes noting their original position. Inspect the commutator for excessive wear such as grooves, chipping, or burned spots. The armature may also have to be replaced. If the condition of the motor is acceptable, install new brushes.

3.3.5.5 Inspect gaskets #1 and #2 and the wiring. Replace or repair the unit as necessary.

3.3.5.6 Replace the motor unit being careful not to bind the cord inside the assembled unit. Replace the adapter mounting plate and the 4 screws.

3.3.5.7 Attach the filter adapter and install a clean filter or the orifice calibration unit and the 18 hole plate.

3.3.5.8 With a variac, apply 50 volts to the motor. Carefully look into the motor exit orifice for excessive sparking. If noted,

the brushes or the armature may be defective. Repair the motor as necessary. Run the motor for 15 minutes at 50 volts to "burn-in" the new brushes. Advance the voltage to 100 volts and again inspect the motor for excessive sparking. Proceed if no problem is apparent. Otherwise, make repairs as necessary by going over the procedures once again and very carefully checking the commutator. Run the motor an additional 15 minutes at 100 volts.

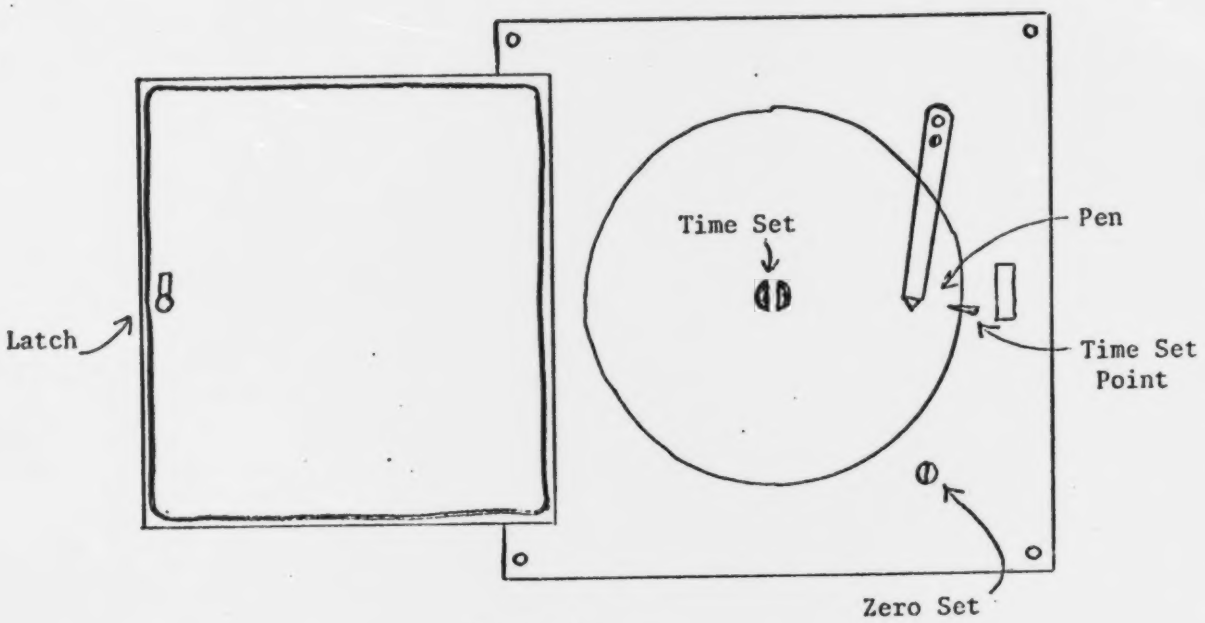
3.4 Recording Pressure Transducer

3.4.1 Figure 4 shows a recording transducer unit. Refer to the figure and the manufacturer's manual for the following procedures.[6]

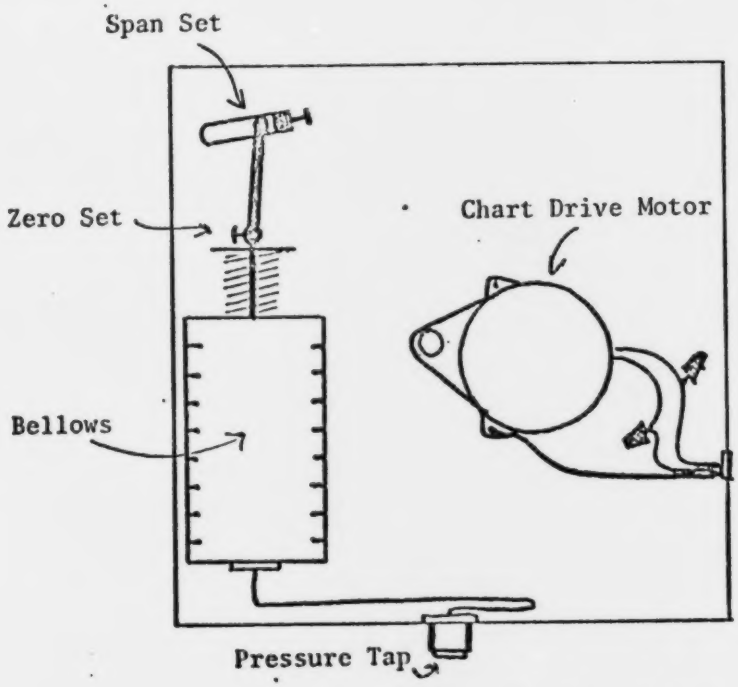
3.4.2 Every pressure transducer should be calibrated when received or when service has been done to the unit.

3.4.2.1 Set up a calibration system as shown in Figure 5. Restrict the open side of the first "tee" until the system may be adjusted easily for pressures from 0-10 inches of water.

3.4.2.2 Using a chart calibrated from 0-10 inches of water (supplied with each new transducer), adjust the transducer zero control for a zero reading. Apply 8-10 inches of water pressure (measured by the water manometer) and determine the reading on the transducer chart. If the chart reading is not within ±1 inch of water pressure, adjust the recorder span control in the back of the unit. Readjust the zero and span controls until the span reading is within ±1 inch of the true pressure and the zero is within ±0.5 inches of zero. Check at least 2 additional points and record the results in the data sheet in Figure 6.



Front View



Back View

Figure 4. Recording Transducer

Figure 5. Transducer Calibration System

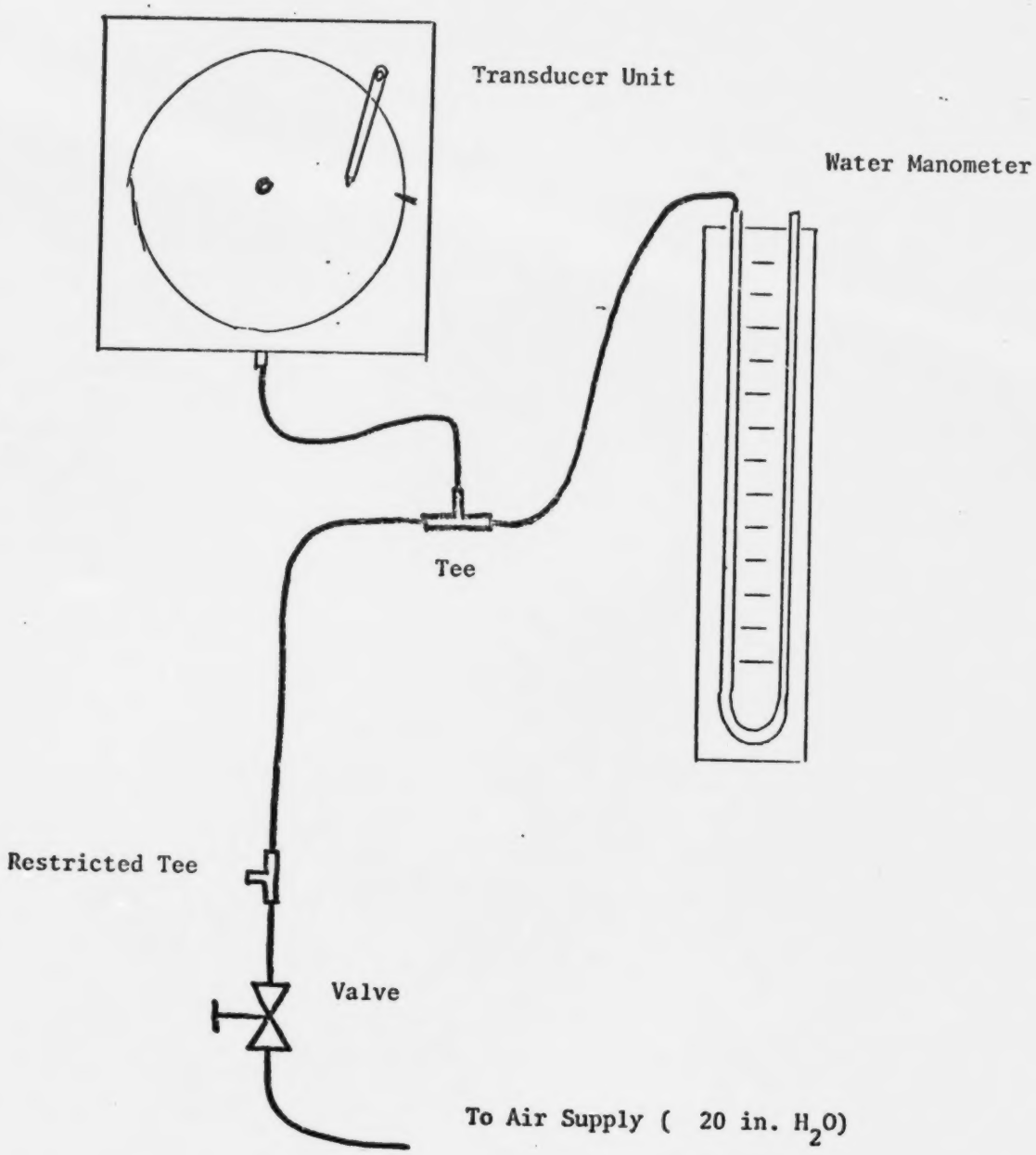


Figure 6.

Tranducer Serial No. _____

Operator _____

Date _____

Point	Actual Pressure in H_2O	Chart Pressure in H_2O	Error in H_2O
Zero			
Span			
1			
2			
3			
4			

3.4.2.3 Adjust the recorder span control by removing the back of the transducer, carefully loosening the adjustment screw, moving the slip arm to a new position, tightening the screw, and checking the zero and span recorder values. Continue this adjustment operation until the recorder span reading is within ±1 inch of the true reading.

This is a delicate operation and may require some practice before the operation can be done quickly. Replace the back of the transducer being careful to seat the gasket properly.

3.4.3 The chart motor may fail occasionally. The CRL maintains some replacement units and upon request will send them out for replacement by District Office personnel.

3.4.4 The pen is the most frequent part to fail. During each site visit, check the pen for dried ink and carefully clean it with acetone, alcohol, or hot water. Also, check the pen arm to be sure it applies sufficient pressure on the pen to the chart. Repair or replace the pen arm as necessary. If the pen does not ink properly, vary the pressure by sliding the pen point on the pen arm toward or away from the chart. It is not necessary to bend the pen arm.

3.5 Voltage Reduction Transformer

3.5.1 Each sampler is equipped with a voltage reduction transformer. This transformer should be wired to provide sufficient drop to make the air flow rate through a clean filter be about 50 cubic feet per minute (1.35 m^3/min).

3.5.1.1 Determine the correct voltage by using a variac to supply the

the motor. Set the variac for an air flow rate of 50 cfm (1.35 m^3/min). Measure the voltage on the variac. Wire the transformer for the voltage drop that will yield a voltage closest to that measured from the variac.

3.5.2 16 volt drop. Figure 7 shows the wiring diagram for a 16 volt drop. The windings X1X2 and X3X4 are wired in parallel. Be careful to not leave any wires exposed that could cause shock injury.

3.5.3 32 volt drop. Figure 8 shows the wiring diagram for a 32 volt drop. Windings X1X2 and X2X3 are in series. The resultant voltage will be about 81 volts. Once again, pay attention to lead dress.

3.6 Each <u>new</u> sampler is equipped with a programmable automatic timer. The operation of the timer is described on the weather door and in the field operations manual.[1]

3.6.1 Any service for this timer should be referred to the CRL at this time. Additional information will be distributed as it becomes available.

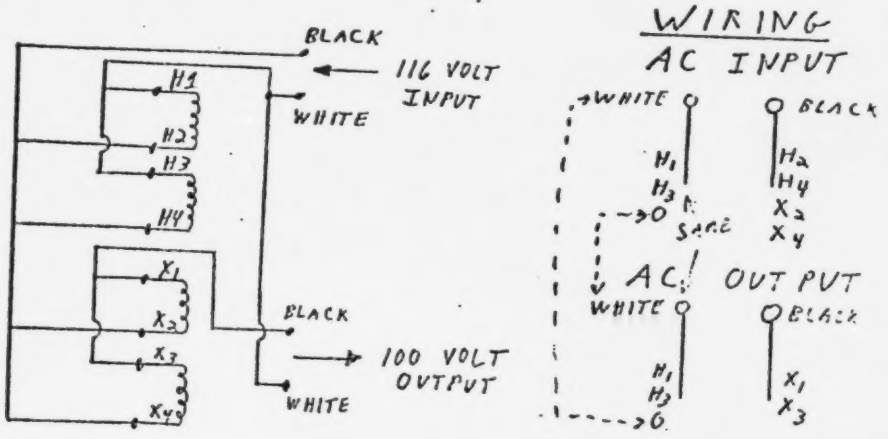
3.6.2 It may be necessary to add an additional outlet to be able to carry enough current to operate both the high volume sampler and gas bubbler. General Metals Works is providing an accessory outlet that can be operated by the timer and provide switched contacts to handle up to 15 amps continuous. Consult the CRL for the availability and installation of these units.

3.6.3 Each elapsed time indicator should be checked for accuracy before installation in the field. Record the elapsed time indicator reading in a log book or on the motor calibration data sheet

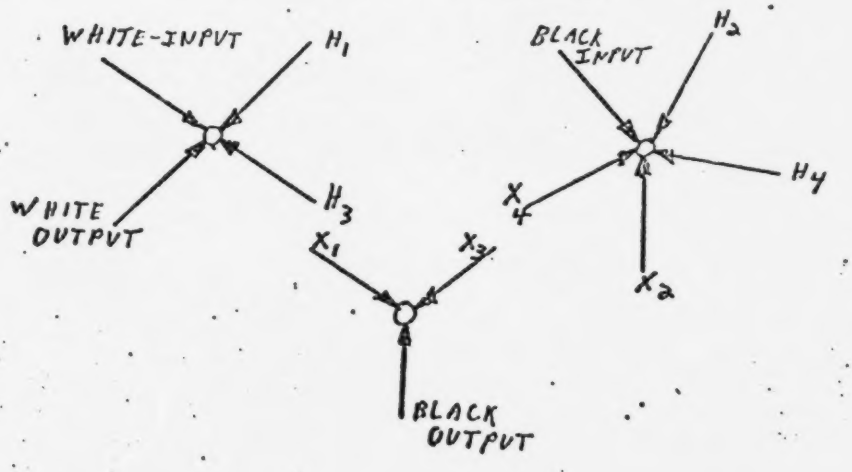
Figure 7.

STEP-DOWN TRANSFORMER

16 VOLT DROP

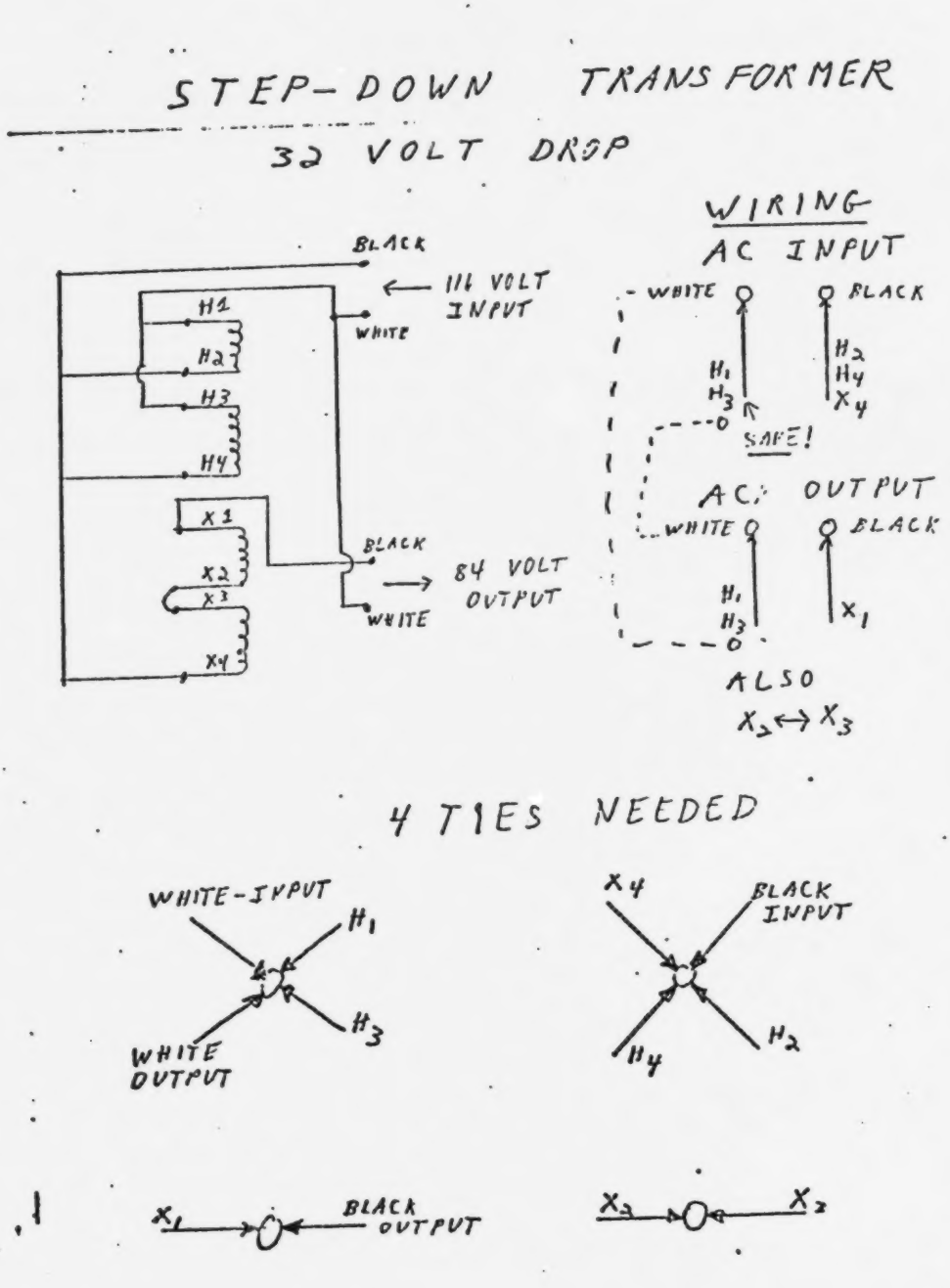


3 TIES NEEDED *



*LEAVE EXTRA CAP IN TRANSFORMER ! (FROM 32 VOLT DROP) JUST IN CASE YOU HAVE TO CHANGE IT BACK LATER.

Figure 8.


STEP-DOWN TRANSFORMER
32 VOLT DROP
BLACK
111 VOLT INPUT
WHITE
H1
H2
H3
H4
X1
X2
X3
X4
BLACK
84 VOLT OUTPUT
WHITE
WIRING
AC INPUT
WHITE
BLACK
H1
H3
H2
H4
X4
SAFE!
AC OUTPUT
WHITE
BLACK
H1
H3
X1
ALSO
X2 ↔ X3
4 TIES NEEDED
WHITE-INPUT
H1
H3
WHITE OUTPUT
X4
BLACK INPUT
H4
H2
X1
BLACK OUTPUT
X3
X2

in figure 13. Record the timer serial number, start the timer, and record the time of day from an accurate clock. Consult the local telephone company or a bank time system if necessary to verify the clock accuracy.

After about 24 hours, record the time of day and elapsed time indicator reading. Determine the difference of the true (clock time) and the indicated time. The error must be less than ±4 minutes to satisfy the Reference Method specifications. If the error is too great, contact the CRL for a new elapsed time indicator.

4.0 High Volume Orifice Calibration Procedures

4.1 High volume sampler motors are calibrated with an orifice calibration unit. The orifice units will be calibrated at the CRL on a yearly basis or at the District Office's request.

4.2 Orifice Calibration

4.2.1 The following equipment is necessary:

4.2.1.1 Positive displacement flowmeter (Rootsmeter)

4.2.1.2 Water manometer (0-16 inches of water)

4.2.1.3 Mercury manometer (0-120 mm Hg)

4.2.1.4 AC voltmeter (0-150 volt)

4.2.1.5 Stopwatch (0.01 sec accuracy)

4.2.1.6 Connecting tubing

4.2.1.7 Logarithmetic Graph Paper (2x3 cycle)

4.2.1.8 Variac (variable voltage transformer)

4.2.2 Set up the calibration system as shown in figure 9.

4.2.2.1 Attach the orifice calibration unit to the intake of the

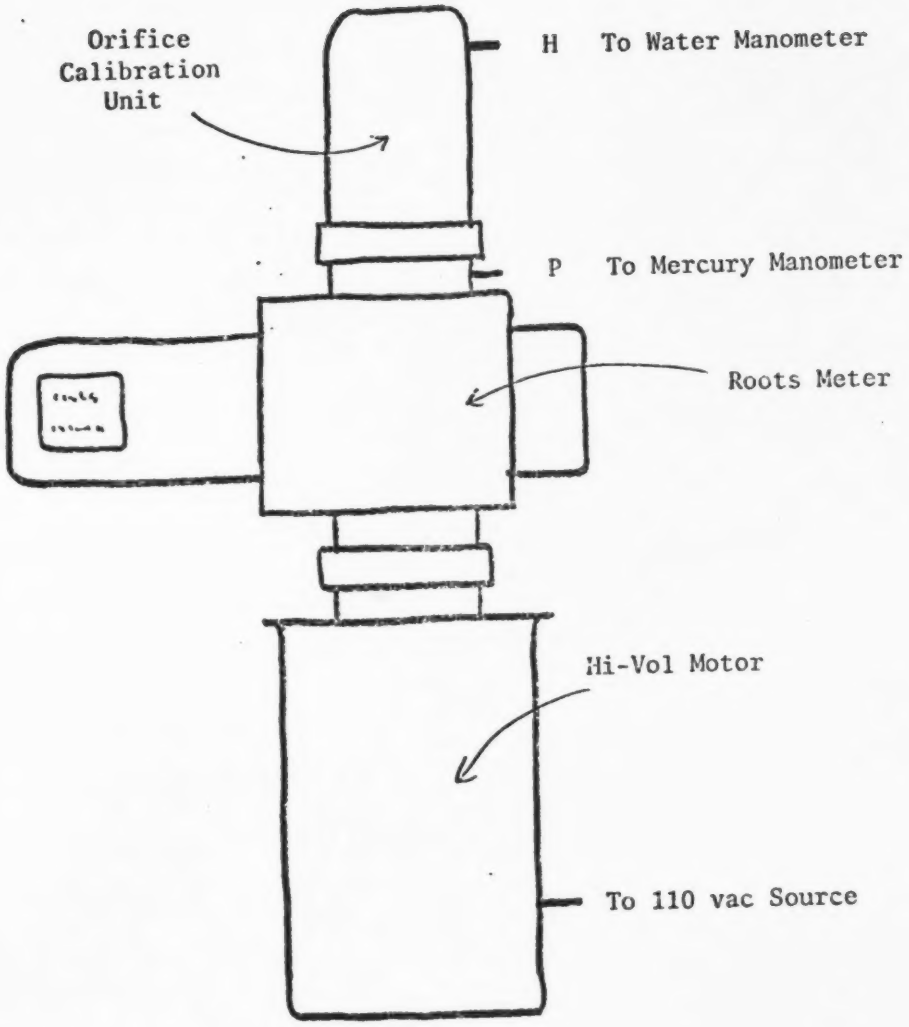


Figure 9. Orifice Calibration Set-up

rootsmeter.

4.2.2.2 Connect one end of the water manometer to the differential pressure tap of the orifice calibration unit; the other end is open to the atmosphere.

4.2.2.3 Connect one end of the mercury manometer to the inlet pressure tap of the rootsmeter; the other end is open to the atmosphere.

4.2.2.4 Attach a high volume sampler motor to the exhaust of the rootsmeter. Attach the variac to the motor power cord and plug the variac into the wall outlet.

4.2.2.5 Record the ambient temperature and pressure on the data sheet in figure 10.

4.2.2.6 Place the load plates , one at a time, between the orifice and rootsmeter. Turn on the high volume sampler motor and allow it to warm up for 10 minutes. Also adjust the variac to obtain 110 VAC to the motor. Maintain this voltage throughout the entire calibration.

4.2.2.7 Record the water manometer and mercury manometer readings on the data sheet.

4.2.2.8 Record the time, in minutes, required to pass the known volume of air.

4.2.2.9 Repeat 4.2.2.6, 7, and 8 until data for all 5 load plates are obtained.

4.2.2.10 Calculate the airflow rate measured by the rootsmeter for each load plate.

$$Q_m = \frac{(P_a - P_m)}{P_a} \frac{V_m}{t}$$

where Q_m = True air flow rate at ambient conditions (m^3/min)

ORIFICE CALIBRATION DATA SHEET

Orifice Calibration Unit S/N _____ Office _____ Date _____

Roots Meter Model No. _____ S/N _____ Hi-Vol Motor S/N _____

Calibrator _____ Auditor _____

Location _____

Ambient Temperature (T) _____ ^{o}K Pressure (Pa) _____ mm Hg Voltage to Motor _____ vac

Load Plate No.	Volume of Air Passed (Vm) ft^3	m^3	Inlet Pressure mm Hg (Pm)	Water Manometer Reading (P_1) mm	in.	Time to Pass Volume min. (t)	Measured Flow Rate m^3/min (Q_m)	Reference Flow Rate m^3/min (Qr)	Error %
5	200	5.66							
7	200	5.66							
10	300	8.50							
13	300	8.50							
18	300	8.50							
audit									

$$Q_m = \frac{(Pa-Pm)\ Vm}{Pa \times t}$$

$$Qr = Qm\left(\frac{\cancel{Pm}\ 298}{Tm\ \ 760}\right)^{\frac{1}{2}}$$

$$\text{Error \%} = \frac{Qo - Qc}{Qc} \times 100$$

Qc = measured value

Qo = point from line

Figure 10. Orifice Calibration Data Sheet

P_a = Ambient Pressure (mm Hg)

P_m = Rootsmeter inlet differential pressure (mm Hg)

V_m = Volume of air measured (m^3)

T = Time to pass V_m (min)

4.2.2.11 Correct each flow rate to reference conditions of 760 mm Hg and 298°K.

$$Q_r = Q_m \left(\frac{P_m}{T_m} \cdot \frac{298}{760} \right)^{\frac{1}{2}}$$

where Q_r = Air flow rate at reference conditions (m^3/min)

T_m = Ambient temperature during calibration (°K)

P_m = Ambient pressure during calibration (mm Hg)

Q_m = True air flow rate at ambient conditions (m^3/min)

4.2.2.12 Plot the water manometer reading (ΔH) vs. reference air flow rate (Q_r) on 2x3 cycle logarithmic graph paper and determine the best fit line. An example of the data is shown in figure 11.

4.2.2.13 Calculate the deviation of each point from the best line and record the result on the data sheet.

$$\text{Percent deviation} = \frac{Q_o - Q_c}{Q_c} \times 100$$

where Q_o = measured point

Q_c = corresponding point from line

If the deviation is ±3% or greater, for any one or more points, the complete calibration must be performed again.

4.3 High Volume Motor and Transducer Calibration

4.3.1 Place the sampler motor in the service position. Figure 12. If the calibration is geing done in the laboratory, an empty shelter or a wooden frame may be used to mount the motor in.

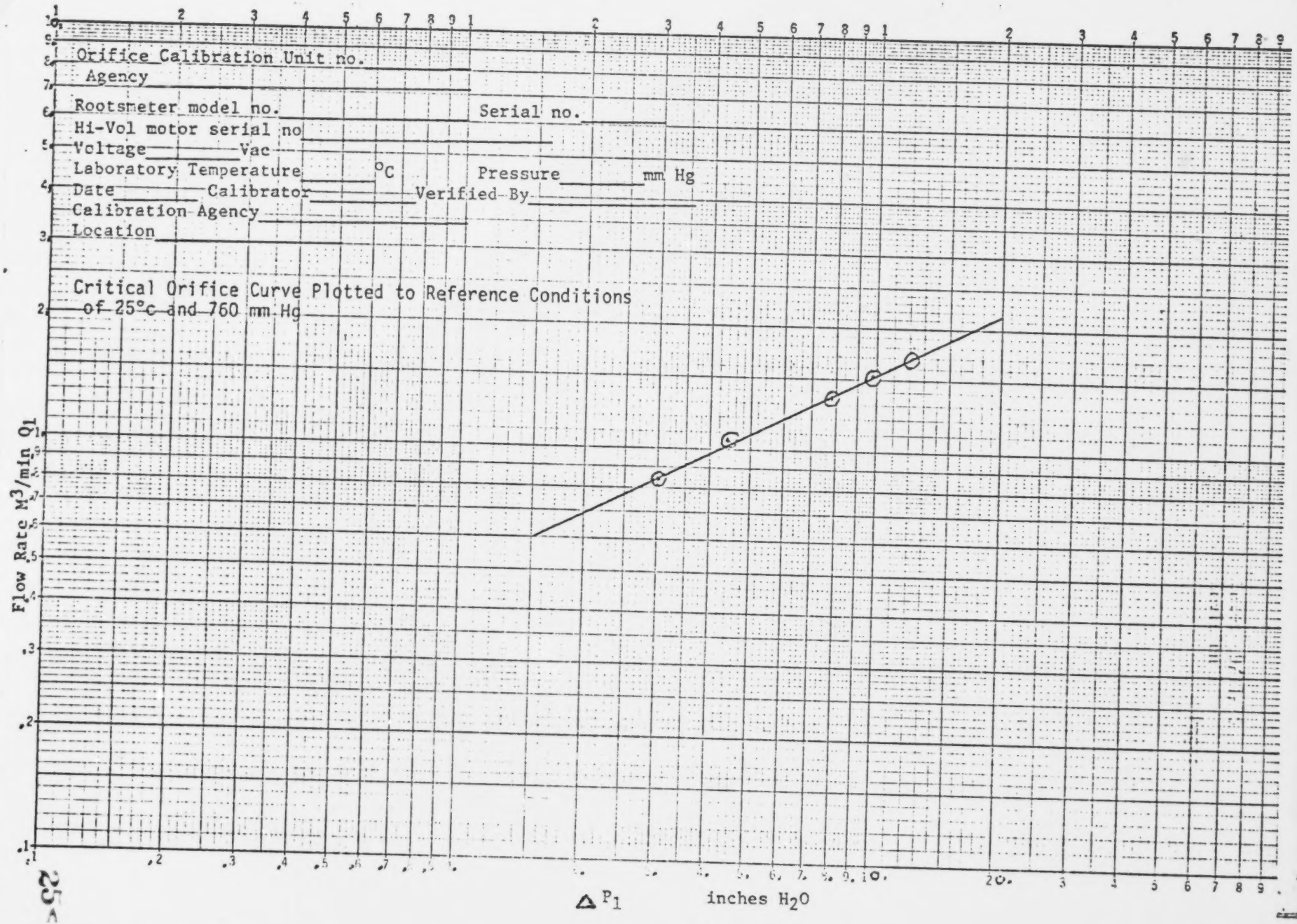

Orifice Calibration Unit no.
Agency
Rootsmeter model no.
Serial no.
Hi-Vol motor serial no
Voltage Vac
Laboratory Temperature °C
Pressure mm Hg
Date
Calibrator
Verified By
Calibration Agency
Location
Critical Orifice Curve Plotted to Reference Conditions
of 25°c and 760 mm Hg
Flow Rate M3/min Q1
ΔP1 inches H2O

Figure 11.

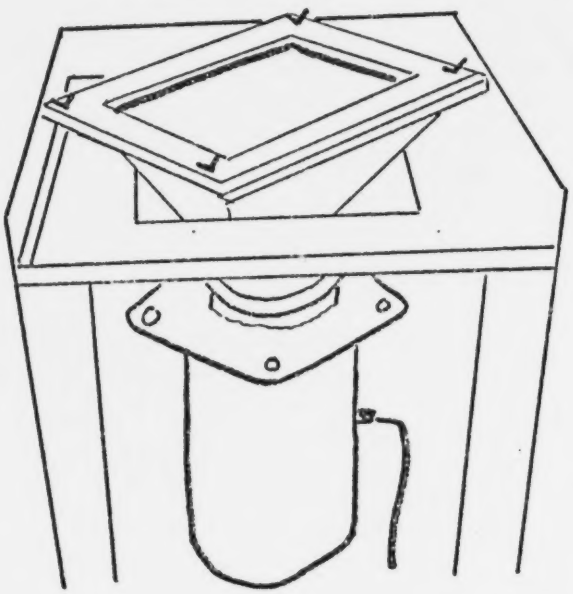


Figure 12. Sampler in Service Position

Figure 13.

HIGH VOLUME SAMPLER CALIBRATION DATA SHEET

Orifice S/N _____ Hi-Vol Motor S/N _____

Transducer S/N _____ Date _____

Sampler Location _____ NASN Site No. _____

Calibrator _____ Office _____

Ambient Temperature _____ Pressure _____ Voltage _____

Clean Filter Reading _____

Calibration Equation Slope: _____ Intercept: _____

Load Plate No.	Manometer Reading in. H_2O	Transducer Chart Reading	Air Flowrate M^3/min	Error %	
18					
13					
10					
7					
5					

4.3.2.0 Calibration Procedure

4.3.2.1 Replace the filter adapter with the orifice calibration unit using the 18 hole load plate.

4.3.2.2 Connect one side of the water manometer to the orifice calibration unit.

4.3.2.3 Install a clean recorder chart.

4.3.2.4 While lightly tapping the recorder, turn the zero adjust screw in the lower right hand corner until the pen reads zero.

4.3.2.5 Connect the motor directly to the variac, bypassing the transformer.

4.3.2.6 Record the ambient temperature and pressure on the data sheet (figure 13).

4.3.2.7 While watching the water manometer, adjust the variac until the differential pressure indicates an air flow rate of 1.7 m^3/min. Record the voltage and maintain the same voltage for the entire calibration.

4.3.2.8 Let the motor run for 10 minutes, then read and record the transducer chart and differential pressure.

4.3.2.9 Repeat steps 4.3.3.4 through 4.3.3.8 for each of the 5 load plates.

4.3.3 Data Calculations

4.3.3.1 For each load plate, determine the air flow rate corresponding to the orifice differential pressure (DH) from the reference orifice calibration curve.

4.3.3.2 Plot the reference flow rate vs. transducer reading on linear graph paper. Determine the line of best fit by eye or least squares. This plot is already at reference conditions and

does not need further correction. See Appendix A.

4.3.3.3 Determine the deviation of the measured points from the best fit line.

$$\text{percent deviation} = \frac{Q_o - Q_c}{Q_c} \times 100$$

where Q_o = Measured point

Q_c = Calculated point from best fit line

If the deviation is ±5 percent or more for one or more points, check the calibration system and recalibrate the point in question. If it still is out of control, recalibrate the motor using all 5 load plates.

4.3.3.4 Replace the filter adapter and voltage reduction transformer. Attach a clean filter and turn on the motor. The flow reading should be between 1.13 and 1.7 m^3/min. The optimum value is 1.5 m^3/min. Record this value on the motor calibration data sheet.

4.3.3.5 Submit copies of both the calibration data sheet and data plot to the CRL.

5.0 High Volume Sampler Field Audit Procedures and Data Reporting

5.1 Each high volume sampler must be audited to verify its calibration in the field and laboratory and proper operation. The air flow rate is audited using an orifice calibration unit, other than the one used to calibrate the motor. At best, the audit should be performed by someone other than the person who calibrated the unit.

5.2 Every 6 months and before any field motor replacement or recalibration, the calibration must be audited. This allows each set

of data to be verified by knowing the initial and final sampler accuracy over the total number of sample periods. This audit is one of the most important factors for the operation of the RAQAN.

5.3 Using a calibrated orifice calibration unit, place the motor into the service position and attach the orifice with the 18 hole plate. Turn on the sampler and allow it to run for 10 minutes. Read the differential manometer pressure and transducer chart and record the data in figure 14.

Repeat this operation for the 13 hole plate.

5.4 Determine the reference flow rates from both the orifice calibration curve and the motor calibration curve. Compare the flow rates and calculate the percent error. If the flow rate error is greater than ±6 percent, check the transducer, tubing, amd motor for damage. Make any necessary repairs and recalibrate the system. If the results are acceptable, continue with routine scheduled maintenance and sampler recalibration.

5.5 Report the calibration audit data to the CRL on the report form (figure 14). Any action taken at the site, in the event of an audit failure should be documented.

6.0 Bubbler Equipment Maintenance Schedule

6.1 Routine maintenance for the gas bubbler sampler should be performed by the station operator and is described in another manual.[2]

6.2 A relative maintenance and audit schedule is shown in Table II. This schedule lists the operations and audits to be performed and should be scheduled to coincide with the high volume sampler maintenance and audit visits.

Figure 14.

Calibration Audit Data Sheet

Site Location _____

Sampler Motor No. _____

Operator _____

Auditor _____

Date _____

Barometric Pressure _____

Ambient Temperature _____

Orifice Serial No. _____

Plate No.	Transducer Chart	Orifice Pressure	Flow rate[1] From Orifice	Flow rate[1] From Sampler	Error[2] %
18					
13					

[1]Flow rates should always be at reference conditions.

[2]Error = $\frac{\text{Orifice Flow Rate - Sampler Flow Rate}}{\text{Orifice Flow Rate}} \times 100$

6.3 The Table lists a number of outputs requested for an operation such as the leak test audit report sheet. These data provide a continuous record of the performance of the sampler and are used to validate data and identify problems. Each operation is described in detail in section 7, 8, and 9.

An operations flow chart is given in figure 15.

7.0 Bubbler Sampler Equipment

7.1 The procedures for the sampler set-up and maintenance assume a unit is being prepared from a new Research Appliance Company (RAC) 5-gas Sampler in the All-Weather Shelter.[7] If a unit is being serviced that has already been assembled, go to the step covering the operation being performed and proceed. These procedures will be applicable to most types of gas bubbler equipment and are not unique to RAC samplers.

7.2 The All-Weather Shelter contains a vacuum pump, vacuum gauge, 5-gas sampling rack, and heater. Figure 16. If the unit is new, extra supplies will be shipped in the 5-gas sampling rack. Save these extra parts. Some can be used for servicing the sampler.

7.3 New samplers are equipped for use with 5 sample tubes. The RAQAN only measures SO_2 and NO_2. Therefore, remove the 3 bubbler trains farthest from the manifold inlet from the rack.

Cap the unused glass manifold ports with polypropylene caps (these caps are used as closures for the sample tubes sent to the station operator and are available from the CRL). It may be necessary to heat the caps to get a good force-fit seal. Small yellow plastic caps are available from the CRL to close the unused vacuum manifold ports. As an alternative, rubber septums or 1/8 inch gas chromatograph

TABLE II.

Step	Time (months)	Operation	Output
1	0	Sampler Preparation	
2	0	Leak Check	Audit Sheet
3	0	Installation	
4	6	System Leak Check	Audit Sheet
5	6	Change Membrane Filters and Septums	Field Inspection Sheet
6	6	System Leak Check	Audit Sheet
7	12	System Leak Check	Audit Sheet
8	12	Change Membrane Filters and Septums	
9	12	Perform Sampler Clean-up	Field Inspection Sheet
10	12	Check Pump System	
11	12	System Leak Check	

Repeat steps 4 through 11 every year.

Bubbler Sampler Operations Flow Chart

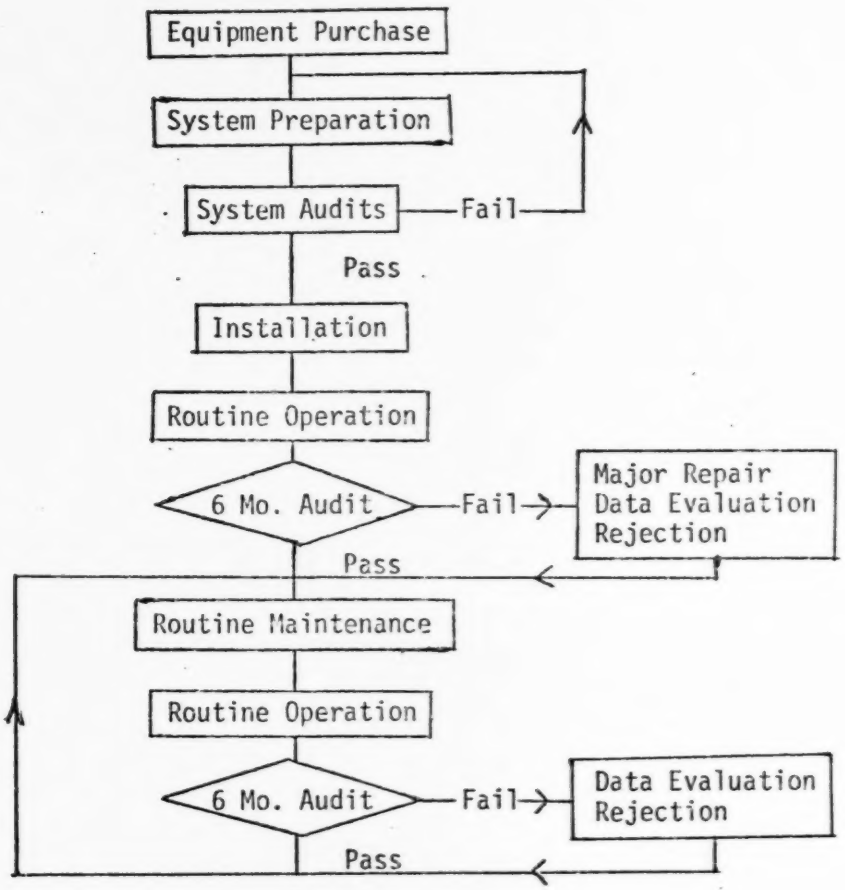


Figure 15.

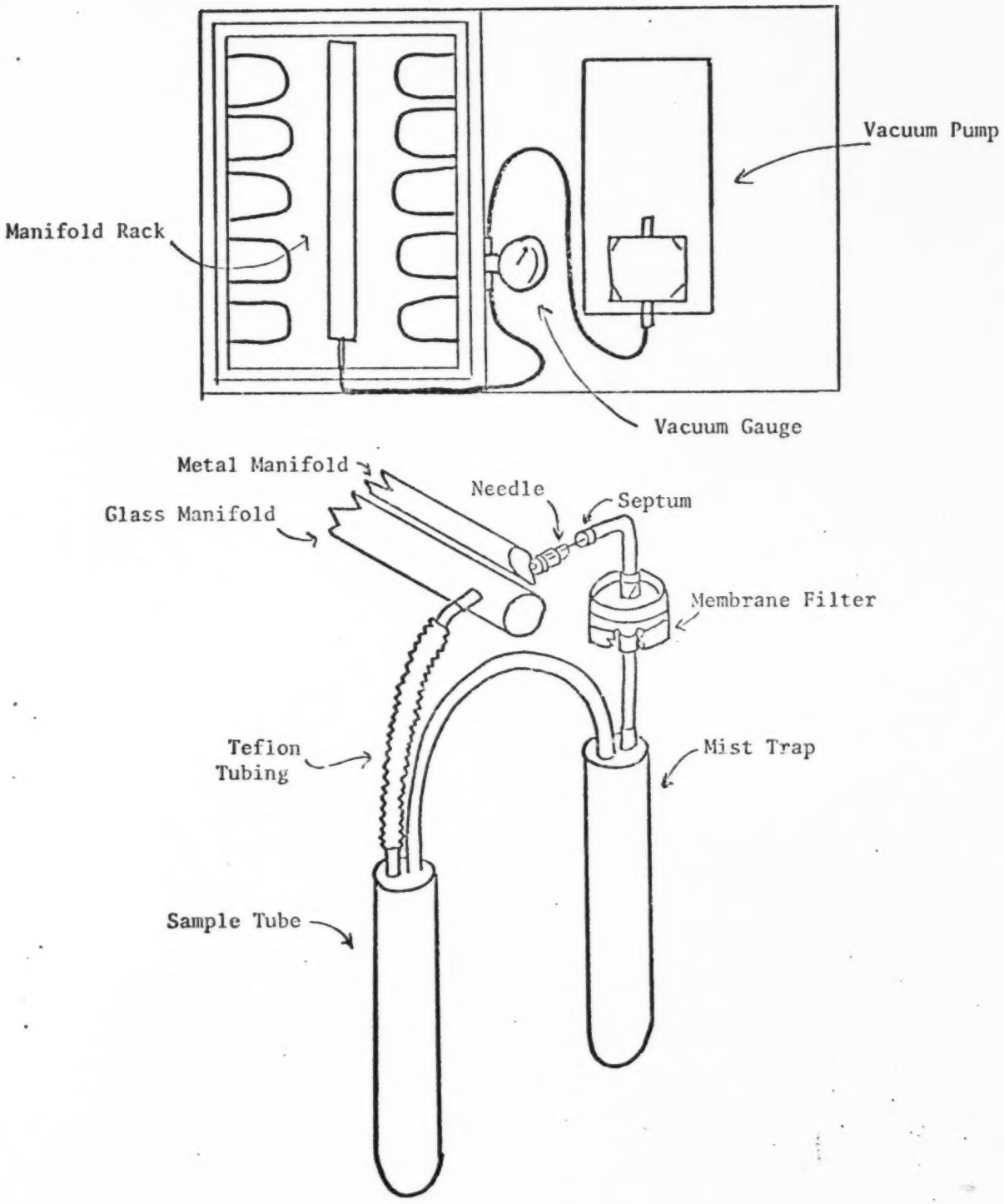


Figure 16. 5-Gas Sampling Rack and Manifold

column caps may be used.

These caps should be checked at installation and each visit thereafter for visual signs of leaks or cracks and replaced if necessary.

7.4 Remove the remaining two sample trains. Note their configuration. Referring to figure 17, press the membrane filter holder together tightly and seal the halves together using acetone or methylene chloride. Every filter unit should be sealed prior to installation to avoid air leaks in the system. Be sure the tygon tubing attaching the filter to the glass tubing is also sealed to the filter housing.

Again, it may be necessary to seal the tubing and filter unit together with acetone.

7.4.1 When replacing the filters during the Semiannual maintenance visits, prepare the assembly as shown in figure 17 in advance. This assembly may be prepared from ¼" I.D. tygon, filter unit, straight and 90° bent pieces of glass and rubber septum. The glass pieces should be reused and the old filter and tubing discarded. The filters should be replaced every 6 months.

7.4.2 Check the tygon tubing for a tight fit at the inlet and outlet ports of the mist trap. Also, be sure the tubing to the absorber tube fits tightly. Replace any tubing that is defective or does not fit tightly on the absorbers or mist traps.

7.4.3 Replace the bubbler trains and attach the teflon inlet tubing directly to the glass manifold. Also attach the rubber tubing from the vacuum pump to the metal vacuum manifold.

7.5 Check the vacuum pump and gauge by turning on the pump and pinching the rubber vacuum tubing tightly. The gauge should read 20 or

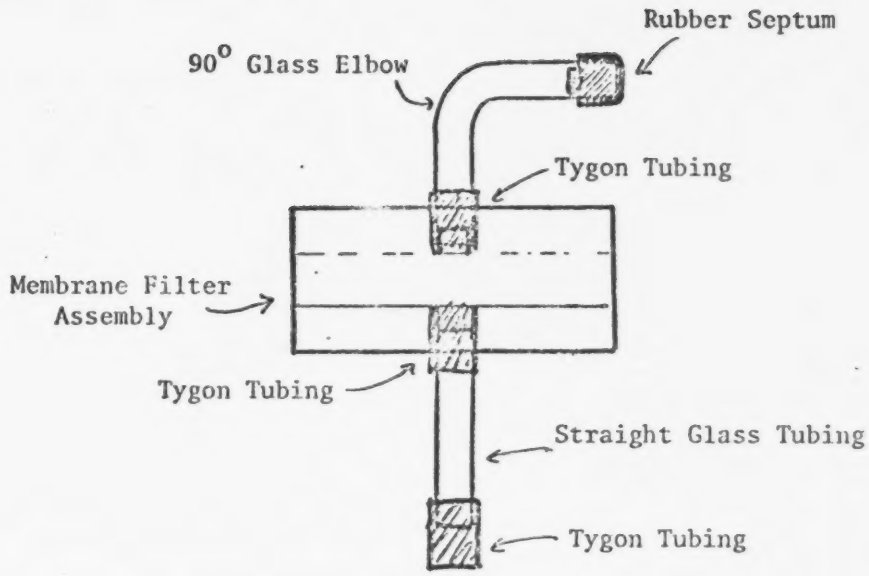


Figure 17. Membrane Filter Unit

greater. If not, the pump or gauge needs repair or replacement.

7.5.1 The gauge may be replaced by simply unscrewing it from the "Tee." When installing the new gauge, use Teflon tape to insure a good seal and avoid damaging the pipe threads.

7.5.2 The vacuum pumps may fail. Usually the pump diaphram and internal gaskets fail before the motor. When a pump fails, it should be replaced with another unit in the field and repaired at the laboratory. Pump rebuild kits will be available upon request from the CRL or the pump may be sent to the CRL for repairs.

7.6 Heater units are provided in the bottom of the bubbler rack section of the All-Weather Sampler. This 35 watt heater should be connected to an always-on power source from late Fall to Spring to avoid sample loss due to freezing. The heater will be warm to the touch when operating properly. The box temperature should be between 10-34^{o}C dependent upon the ambient temperature.
If a unit fails, replace the heater. The CRL will supply extra heaters upon request.

7.7 Replace the sampling train; be sure all the tubing is properly attached. Plug the pump into a timer switched outlet and the heater into an always-on outlet if the weather is cold.
The sampler should be operated only on sampling days with needles and absorbing solutions in place.

8.0 Bubbler Audit Procedures

8.1 Air leaks are a major source of error for gas sampling systems. The bubbler trains can leak air at the rubber septum, membrane filter, and all tubing connections. Any air leak will cause the

data to be biased low. Therefore, after preparation, 6 months of operation or service, the system should be checked for leaks.

8.2 Referring again to figure 16, install the dummy absorbing tubes. Attach the water manometer from an orifice calibration unit to the inlet of the glass manifold. Attach a hypodermic needle to one of the open vacuum manifold ports. Close the other with a plastic cap, rubber septum, or another needle.• Turn on the vacuum pump. Push the needle through the rubber septum and carefully watch the vacuum develop on the water manometer. When 10-15 inches of water differential pressure develops, pull the needle from the septum. Both bubbler trains and glass manifold are now sealed. Record the differential pressure in figure 18.

Wait one (1) minute and record the final differential pressure in figure 18. Determine the difference. If the differential pressure dropped more than 1 inch of water, a leak exists. Check all joints and seals and repair the leak. Repeat the test until the change in differential pressure is 1 inch or less. Report the data to the CRL.

This is a requested output (Table II) and must be performed regularly.

9.0 RAQAN Station Set-up

9.1 When locating air monitors, adhere to siting guidelines OAQPS No. 1.2-012 Table I as closely as practicable.

9.2 The High Volume Air Sampler and Gas Bubbler must be mounted securely to a sturdy base,and the base must be weighed down with building blocks to prevent being blown over by high winds.

9.3 Material List for High Volume Sampler Installation

Figure 18.

Bubble System Leak Check

Sampler Location _____

Sampler Serial No. _____

Auditor _____ Date _____

New Unit ☐ , before service ☐ after service ☐

Test 1

Set Pressure:

Initial Differential Pressure _____ in. H_2O

Wait 1 minute:

Final Differential Pressure _____ in. H_2O

Difference _____ in. H_2O

If Difference is 1 in. H_2O or less, unit passes test. If greater than 1 in. H_2O, repair leaks, perform another test, and repeat process until acceptable criteria are met.

Test 2

Set Pressure:

Initial Differential Pressure _____ in. H_2O

Wait 1 minute:

Final Differential Pressure _____ in. H_2O

Difference _____ in. H_2O

9.3.1 4 - 2" x 4" x 6' lumber

9.3.2 2 - 1" x 6" x 18" lumber

9.3.3 2 - building blocks

9.3.4 8 - ¼" x 3" lag screws

9.3.5 4 - ¼" x 2½" round-head stove bolts and nuts

9.3.6 16 - 5/16" I.D., 3/4" O.D. flat washers

9.3.7 8 nails

9.3.8 ¼" thick, 14" x 14" plywood

9.4 Paint or treat all of the lumber with 2 coats of paint or wood preservative. Let it dry 24 hours between coats and before installation.

9.5 Sampler station set-up. Figure 19 shows a top view of the support necessary for a high volume shelter. The following procedures are for placement of a single hi-vol only. However, by using the parts list in section 9.7, and making the appropriate changes in the procedure, a support for both a hi-vol and a bubbler can be constructed as in figure 20.

9.5.1 Set the Hi-Vol Sampler on a ¼" thick 14" square section of plywood or similar material. This will provide the clearance between the building roof and the sharp corners of the shelter legs. Lay a 2 x 4 on the roof with the wide side against the shelter legs. Center the 2 x 4 and drill 5/16" holes through the 2 x 4 and the shelter legs. Bolt the shelter to the 2 x 4 with ¼" x 2½" stove bolts, nuts, and washers.

9.5.2 Do the same with the second 2 x 4.

9.5.3 Remove the ¼" thick 14" square section of plywood.

9.5.4 Nail the 1" x 6" x 18" boards across the top of the 2 x 4's,

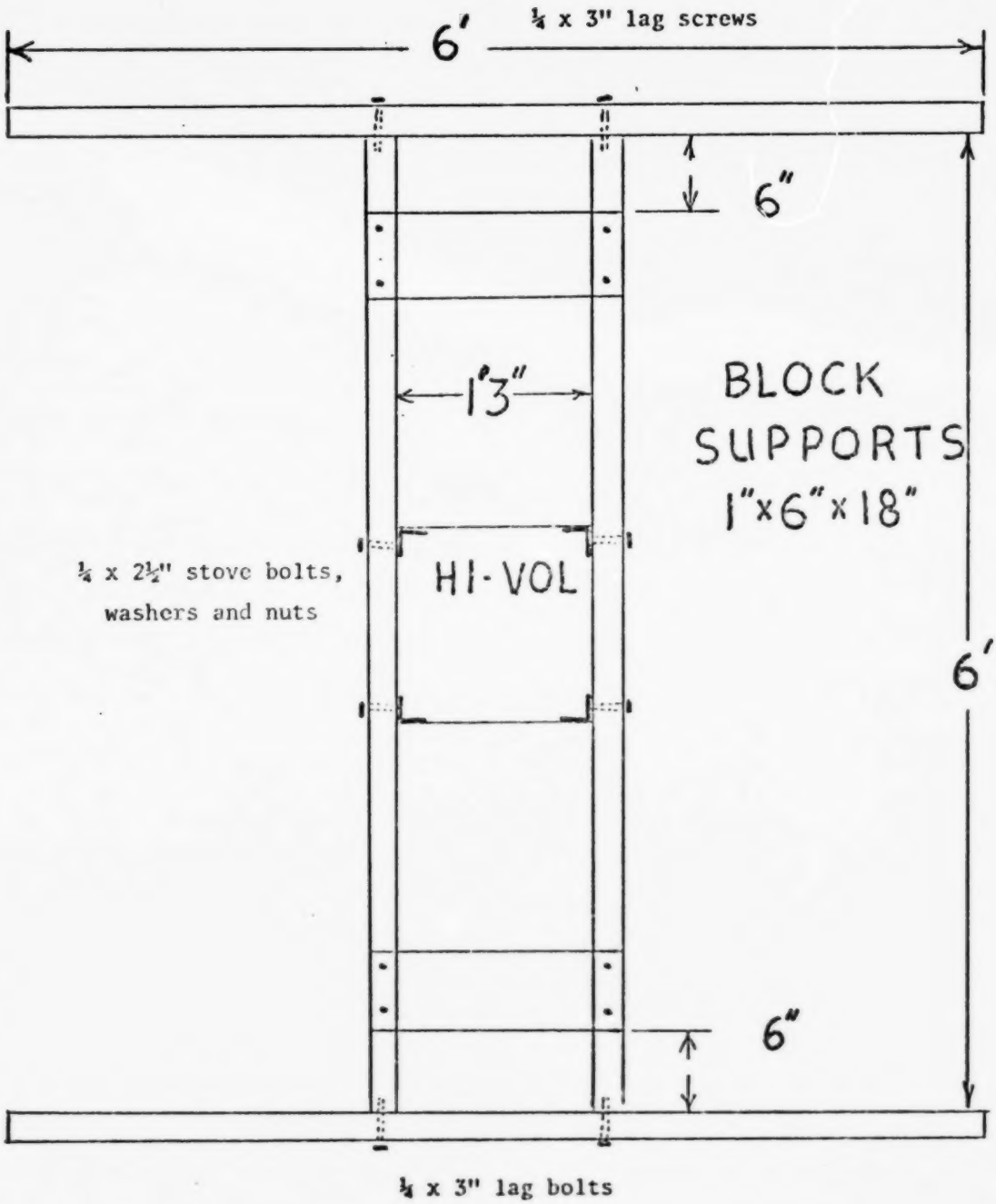


Figure 19. High Volume Sampler Support

six inches from the end of the 2 x 4's. This will support the building blocks.

9.5.5 Fasten the 3rd 2 x 4 against the ends of the pair of 2 x 4's supporting the shelter. Use 4 - ¼" x 3" lag screws.

9.5.6 Fasten the 4th 2 x 4 against the opposite ends of the 2 x 4's supporting the shelter.

9.6 For the power line use a weatherproof three conductor #16 gauge cable if only one Hi-Vol sampler is being installed.

9.6.1 If a Hi-Vol Sampler and a Gas Bubbler are to be installed, use #14 gauge 3 conductor cables. Use a weatherproof outlet box and three prong receptacle.

9.7 Material List For Hi-Volume Sampler and Gas Bubbler Installation

9.7.1 2 - 2" x 4" x 6" lumber

9.7.2 2 - 2" x 4" x 8" lumber

9.7.3 2 - 1" x 6" x 18" lumber

9.7.4 8 - ¼" x 3" lag screws

9.7.5 4 - ¼" x 1½" lag screws

9.7.6 4 - ¼" x 2½" stove bolts and nuts

9.7.7 16 - 5/6" I.D., 3/4" O.D. flat washers

9.7.8 2 - building blocks

9.7.9 8 - nails

9.7.9.1 ¼" x 14" x 14" plywood

9.7.9.2 2 - ¼" x 5/8" round-head stove bolts

9.7.9.4 1 - ½" x 10' thinwall conduit

9.7.9.5 12' - 5/16" teflon tubing

9.7.9.6 1 - polypropylene funnel - ¼" O.D. stem

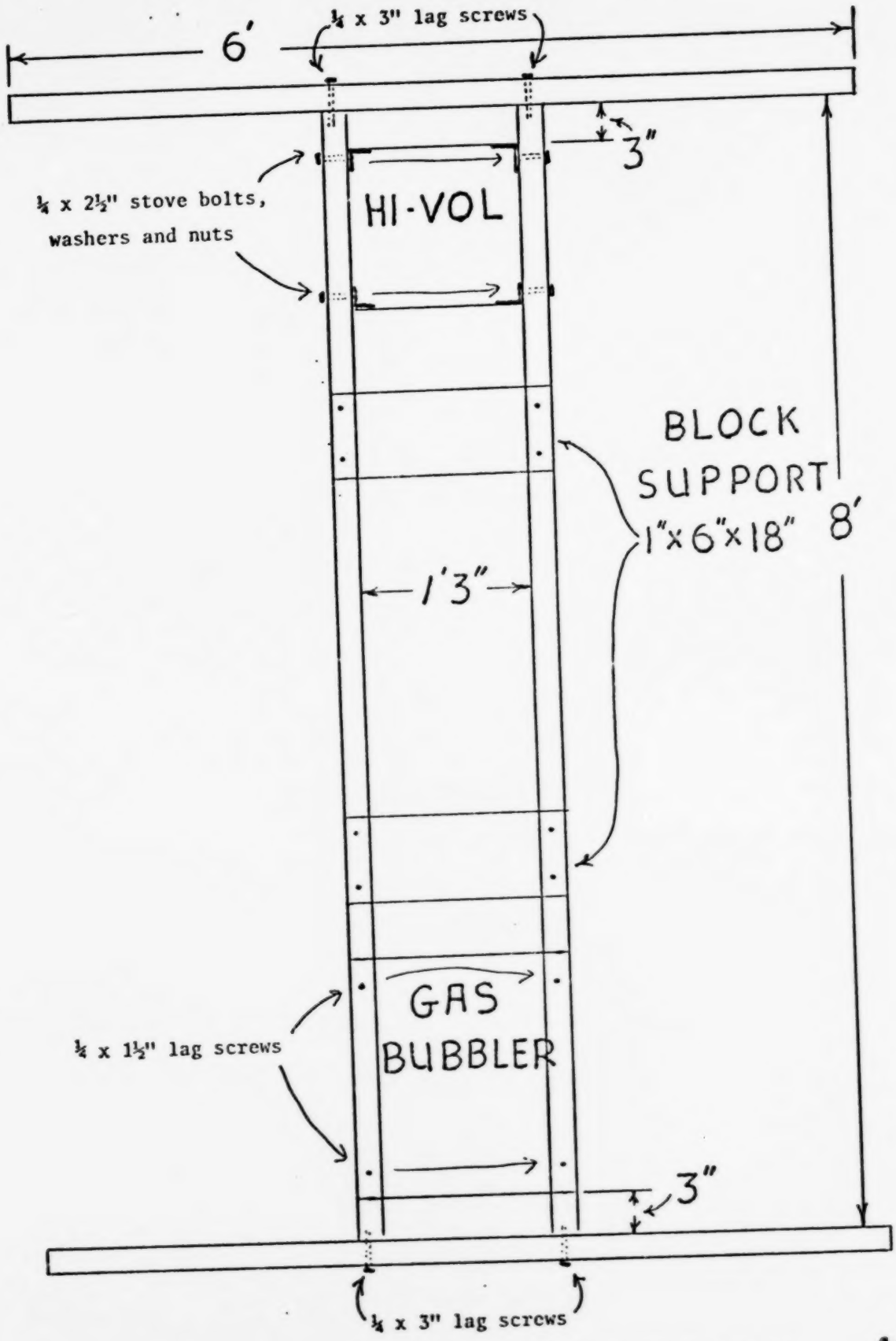


Figure 20. High Volume and Bubbler Sampler Support

10.0 Sampler Audit Data Evaluation Criteria

10.1 Sampler calibration and system audits are described within the test, i.e., Hi-vol flow rate audit error limit is ±6 percent. However, to assess the overall quality of the monitoring data, the audit data must be summarized and reported to cause acceptance or rejection of the monitoring data.

At the time of this writing, no sufficient amount of field audit data are available to set limits and specific evaluation criteria. However, as soon as 6 months of auditing data are available, this section will be revised to describe specific evaluation techniques for determining the quality of the air monitoring data.

11.0 During each site visit, as well as performing routine maintenance, a record should be made of the action taken and any deficiencies that must be corrected during the next visit.

11.1 Figures 21 and 22 show suggested inspection record sheets. (Prepared by Peter Gillen of MWDO) The sheets should be filled out for each site after each visit. A copy should be submitted to the CRL.

Figure 21.

U.S. EPA

Equipment Evaluation
Hi-Volume Air Sampler

Hi-Vol Serial No. _____

RASN Site No. _____

Site Location _____

Street Address _____

City & State _____

DATES

Inspection _____

Last Calibration _____

Last Brush Change _____

Item	Deficiency	Action taken	Action Required at next inspection/visit
Shelter Shelter base Weights Cover Latch			
Motor housing Rotor Brushes			
Filter cone Screen Pins Wing nuts Hold-down plate Filter gasket Rubber gasket			
Transducer (S/N) Tubing			
Voltage reducer			
Timer (S/N)			
Electrical cords Electrical plugs			

Comments on changes affecting height of site, obstructions or factors affecting the site and other comments.

Figure 22.

U.S. EPA

Equipment Evaluation
Gas Bubbler

Bubbler Serial No. _____ Date

RAQAN Site No. _____ Inspection _____

Site Location _____

Street Address _____

City & State _____

Item	Deficiency	Action taken	Action Required at next inspection/vis
Shelter Box			
Shelter Base			
Weights			
Pump			
Vacuum gage			
Vacuum tubing			
Electrical cord			
Electrical plugs			
Timer			
Probe			
Tubing			
Funnel			
Heater			
Heater cord			
Bubbler insulation			
Bubbler rack			
Glass manifold			
Brass manifold			
Manifold plugs			
Tubing			
Tubing connections			
Demisters			
Demister sponge or wool			
Demister connections			
Membrane filters			

References

[1]"Regional Air Quality Assurance Network - Particulate Sampling Procedures (High Volume Method)," EPA, Central Regional Laboratory, August, 1975.

[2]"Regional Air Quality Assurance Network - Sulfur Dioxide and Nitrogen Dioxide Sampling Procedures - Twenty-four Hour Bubbler Method," EPA, Central Regional Laboratory, August, 1975.

[3]"Region V Air Quality Assurance Program - The Determination of Suspended Particulates - High Volume Method - Laboratory Operations Manual," EPA, Central Regional Laboratory, July, 1975.

[4]"Region V Air Quality Assurance Program - The Determination of Sulfur Dioxide and Nitrogen Dioxide by the Gas Bubbler Method - Laboratory Operations Manual," EPA, Central Regional Laboratory, July, 1975.

[5]"Operators Manual - Model GMWL 2000 and Model GMWL 2000H," General Metals Works, Cleveland, Ohio.

[6]"Operating Manual for Dickson Recording Instruments," The Dickson Company, Addison, IL, 1973.

[7]"Operating Instructions for 5-Gas Collector Sampler, Catalog No. 2333A," Research Appliance Company, Allison Park, PA, April, 1972.

JL 7/25/75

Appendix A

TEMPERATURE AND PRESSURE CORRECTION SCHEME

The type of temperature and pressure corrections for high volume air sampler calibrations and flow rate measurement(s) have been questioned for a considerable length of time. In February, 1975, Dr. Randy Korda of the Wisconsin Department of Natural Resources and I discussed the topic at length and agreed upon a correction scheme. The equations are as follows:

1. Orifice calibration with a positive displacement flow meter (Roots Meter):

$$Va = \frac{(P_1 - \Delta P)}{P_1} Vm$$

Va = Air volume at atmospheric conditions T_1 and P_1 (M^3)

P_1 = Barometric pressure (mmHg)

ΔP = Pressure drop at inlet of roots meter (mmHg)

Vm = Uncorrected volume measured by roots meter (M^3)

$$Q_1 = Va/t$$

Q_1 = Air flow rate at atmospheric conditions corresponding to a differential orifice pressure, ΔH, (M^3/min)

t = Time to pass air volume Va

$$Q_R = Q_1 \left(\frac{P_1}{T_1} \frac{Tr}{PR}\right)^{\frac{1}{2}}$$

Q_R = Air flow rate at reference conditions T_R and P_R (M^3/min)

T_1 = Ambient temperature at time of orifice calibration (^oK)

P_1 = Ambient pressure at time of orifice calibration (mmHg)

T_R = 298^oK

P_R = 760 mmHg

1

The orifice calibration curve is constructed by plotting ΔH vs. Q_R on log-log graph paper. This curve is the same as if the orifice had been calibrated at reference conditions.

2. Sampler Calibration with a Calibrated Orifice Unit.

Orifice differential pressures (ΔH) and flow indicator device readings(I) (recording transducer) are recorded for each of 5 load plates. The flow rate at reference conditions is determined from the ΔH vs. Q_R curve and is plotted on linear graph paper vs. indicator readings (Q_R vs. I). This plot is the flow rate at reference conditions and is not dependent upon the conditions when the sampler was calibrated.

3. Air Volume Sampled Determination.

The reference flow rate, Q_R, from I is corrected to the conditions during sample collection.

$$Q_2 = Q_R \frac{(P_R\ T_2)^{1/2}}{(T_R\ P_2)}$$

Q_2 = Air flow rate at field conditions T_2 and P_2 (M^3/min)

T_2 = Field temperature during sample collection (^oK)

P_2 = Field pressure during sample collection (mmHg)

Note that this correction yields the flow rate, Q_2, that would be observed directly from the motor calibration curve, Q_R vs. I, if the motor calibration had been performed and reported at field conditions.

The air volume sampled at field conditions is:

50

$V_2 = Q_2 \times t$

V_2 = Air volume sampled at field conditions T_2 and P_2 (M^3)

t = Sampling time (min.)

The volume is corrected to reference conditions using the gas law equation:

$$V_R = V_2 \left(\frac{P_2}{T_2} \frac{Tr}{Pr}\right)$$

This volume is used to calculate the particulate concentration.

4. The air flow rate and volume correction scheme described here has been verified experimentally at the Central Regional Laboratory and found to yeild errors of 2% or less from the actual values determined with positive displacement flow meters.

An orifice was calibrated at 26°C and at 53°C and the ΔH vs. Q_R curves drawn to reference conditions as described in Section 1. The differences between the two calibrations are shown below:

Load Plate No.	ΔH	Q_R (26° Calibration)	Q_R(53° Calibration)	% Error
18	11.6	1.65	1.64	-0.6
13	9.68	1.49	1.50	0.7
10	7.48	1.31	1.32	0.7
7	4.76	1.07	1.06	-0.9

If the correction was not applied, the errors would be from 4 to 5 percent.

To verify the sampler corrections in sections 2 and 3, a high volume sampler was calibrated at 26°C and the flow rate vs. flow indicator reading (I) curve drawn to reference conditions as described in Section 2. Air was then sampled at 53°C and the flow rate measured by I and a positive displacement flow

meter. The flow rates were then corrected to reference conditions and the air volume sampled determined.

The volumes found from the flow indicator reading and the roots meter were compared.

$I(cmH_2O)$	$Q_R(M^3/min)$	V_R[1](CALC M^3)	V_R[2](Roots Meter M^3)	% Error
16.7	1.64	94.6	96.0	-1.5
14.1	1.50	85.4	85.9	-0.6
11.0	1.32	75.1	76.0	-1.2
7.1	1.06	60.8	61.4	-1.0

[1] Air volume sampled at reference conditions for 60 minutes.

[2] Air volume measured by Roots Meter and corrected to reference conditions for 60 minutes.

Once again, had no corrections been applied, the error would have been 3 to 5 percent for this data.

Therefore, the procedures described here and by Dr. Korda minimize the errors in air volume measurement to less than 2 percent. The corrections are simple to employ and improve the quality of the data.

52